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Uranium-lead geochronological results from the Churchill River–Southern Indian Lake transect, northern Manitoba[1,2]

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Rayner, N. and Corrigan, D., 2004: Uranium-lead geochronological results from the Churchill River–Southern Indian Lake transect, northern Manitoba; Geological Survey of Canada, Current Research 2004-F1, 14 p.

Abstract: Uranium-lead geochronological results are presented from northwestern Manitoba. A rhyolite porphyry from the Rusty Lake Belt was dated by thermal ionization mass spectrometry (TIMS) at 1883 ± 2 Ma. Sensitive High Resolution Ion Microprobe (SHRIMP) analysis of detrital zircons from the overlying Powder Magazine turbidite suggests a single volcanic provenance and a maximum age of deposition of 1880 ± 4 Ma. Detrital zircons from a Partridge Breast Belt conglomerate indicate a largely arc source (ca. 1.9 Ga), but contain a large proportion of 2.3 to 2.5 Ga zircons. The maximum age of deposition is 1886 ± 4 Ma. SHRIMP dating of a quartz diorite in the Southern Indian Domain yields a crystallization age of 1889 ± 11 Ma, but the quartz diorite contains numerous 2.4 to 2.5 Ga inherited zircons. A megacrystic granite and a monzodiorite from the Southern Indian Domain give indistinguishable TIMS ages of 1829 ± 1 Ma and 1829 ± 2 Ma, respectively, whereas a monzogranite yielded a ca. 1850 Ma (TIMS) age.

Résumé : Des données géochronologiques U-Pb sont présentées pour le nord-ouest du Manitoba. Un porphyre rhyolitique de la ceinture de Rusty Lake a été daté par spectrométrie de masse à thermoionisation (TIMS) à 1883 ± 2 Ma. L'analyse à la microsonde ionique à haute résolution et à haut niveau de sensibilité (SHRIMP) de zircons détritiques provenant de la turbidite sus-jacente de la formation de Powder Magazine indique que ces zircons sont d'origine exclusivement volcanique et que l'âge maximal de dépôt est de 1880 ± 4 Ma. Des zircons détritiques d'un conglomérat de la ceinture de Partridge Breast proviennent principalement d'un arc (environ 1,9 Ga), mais le conglomérat contient aussi une grande proportion de zircons de 2,3 à 2,5 Ga. L'âge maximal de dépôt est de 1886 ± 4 Ma. La datation à la microsonde SHRIMP d'une diorite quartzique dans le domaine de Southern Indian donne un âge de cristallisation de 1889 ± 11 Ma; cependant, la diorite quartzique contient de nombreux zircons hérités datant de 2,4 à 2,5 Ga. La datation par spectrométrie TIMS d'un granite mégacristallin et d'une monzodiorite provenant du domaine de Southern Indian a donné des âges indifférenciables de 1829 ± 1 Ma et de 1829 ± 2 Ma, respectivement, tandis que la datation par la même méthode d'un monzogranite a livré un âge de 1850 Ma environ.

[1] Contribution to the Targeted Geoscience Initiative (TGI)
[2] Contribution to the Northern Resources Development Program

INTRODUCTION

The Churchill River–Southern Indian Lake transect is part of a Targeted Geoscience Initiative in the Granville Lake–Southern Indian Lake area, northern Manitoba; it is a multidisciplinary geoscience project undertaken in partnership with the Manitoba Geological Survey (Fig. 1). The overall objective of this project is to provide an integrated and updated view of the geological and tectonostratigraphic framework as well as the economic potential of the Lynn Lake–Leaf Rapids area. In this paper, we present results from U-Pb dating of plutonic, volcanic, and sedimentary protoliths that provide constraints on the timing of protolith formation and sediment deposition. The samples presented herein form a part of a suite collected during the first full field season in 2001 in the Southern Indian Domain and Ruttan mine area (*see* Fig. 1, 2).

REGIONAL GEOLOGY

Supracrustal and associated plutonic rocks along the northern flank of the Trans-Hudson Orogen in Manitoba have been previously assigned to three main lithological packages, the Kisseynew, Lynn Lake–Leaf Rapids, and Southern Indian domains (Hoffman, 1988). The Kisseynew Domain comprises mainly upper-amphibolite- to granulite-facies metaturbidite of the Burntwood Group, which is unconformably overlain to the north by molassic sedimentary rocks of the Sickle Group. In Manitoba, the Kisseynew Domain is flanked to the north by the Lynn Lake–Leaf Rapids Domain (Fig. 1), which comprises ca. 1.90 to 1.88 Ga (Baldwin et al., 1987) volcanic rocks and associated sedimentary rocks (Syme, 1985; Ames and Taylor, 1996; Zwanzig et al., 1999). The Southern Indian Domain flanks the Lynn Lake–Rusty Lake Belt to the north and for the most part correlates with the Rottenstone Domain in Saskatchewan (Fig. 1). It is dominated by granitoid orthogneiss and sedimentary rocks, as well as subordinate volcanic rocks. Recent work on Reindeer Lake in Saskatchewan has led to the recognition of at least two distinct sedimentary basins in the Rottenstone Domain, the Milton Island assemblage, interpreted as a forearc or accretionary complex formed north of the advancing La Ronge–Lynn Lake arc, and the Park Island assemblage, interpreted as forming part of a foreland or molasse-type basin (Corrigan et al., 1999b). Both assemblages are continuous in the Southern Indian Domain. The Pukatawakan Bay area contains minor mafic volcanic rocks as well as sedimentary rock historically linked to the Sickle Group. Plutons were examined to provide constraints on the local and regional magmatic evolution. The Partridge Breast

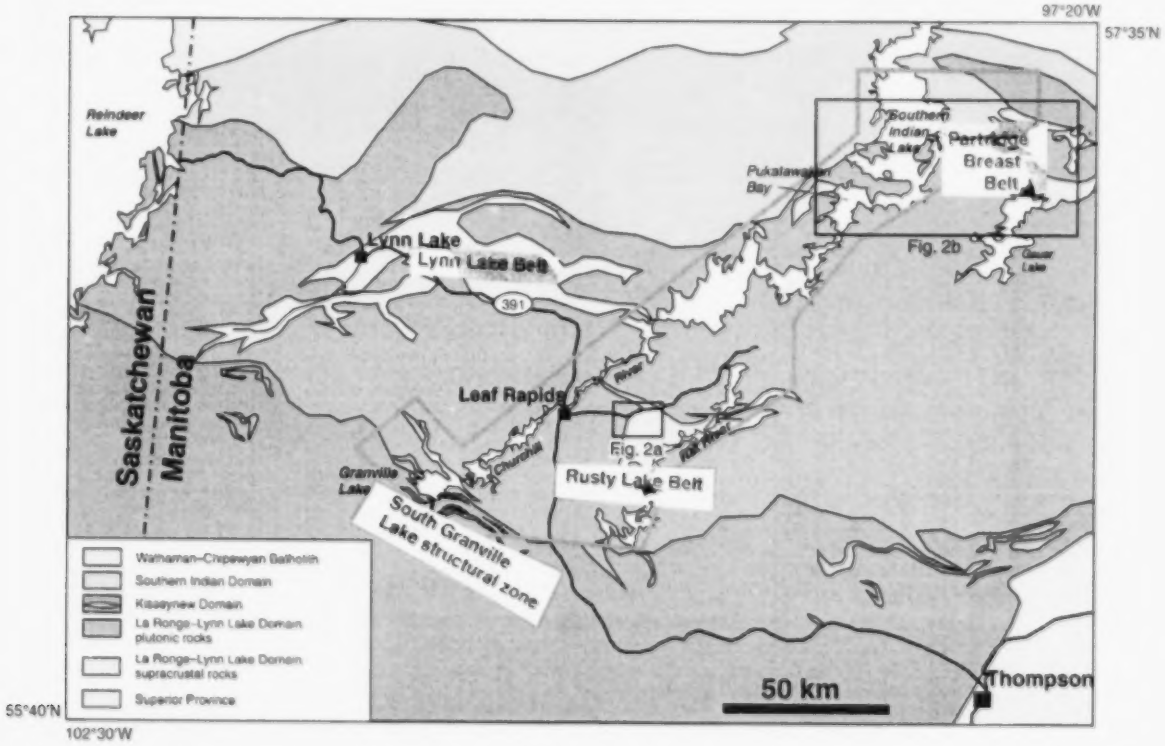

Figure 1. *Main geological domains along the northern flank of the Trans-Hudson Orogen. The scope of the GSC's contribution to the Granville Lake–Southern Indian Lake TGI is outlined in blue.*

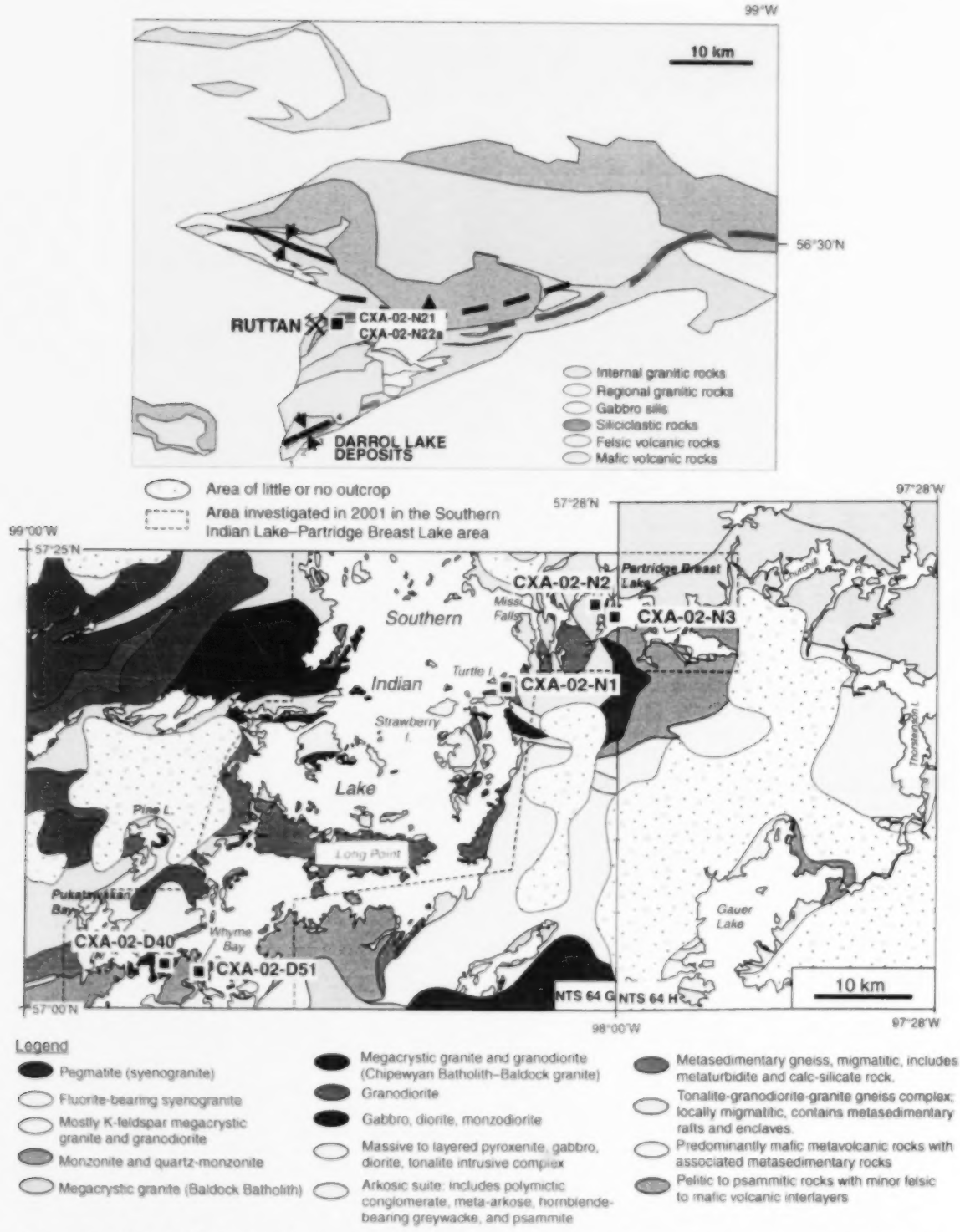

Figure 2. *a) Simplifed bedrock geology map of the Ruttan mine area (*modified from *Ames and Taylor, 1996) showing the U-Pb geochronology sampling localities. See Figure 1 for location. b) Simplified geological map of the Southern Indian Lake–Partridge Breast Belt area (Corrigan et al., 2002) showing the main sampling localities for U-Pb geochronology.*

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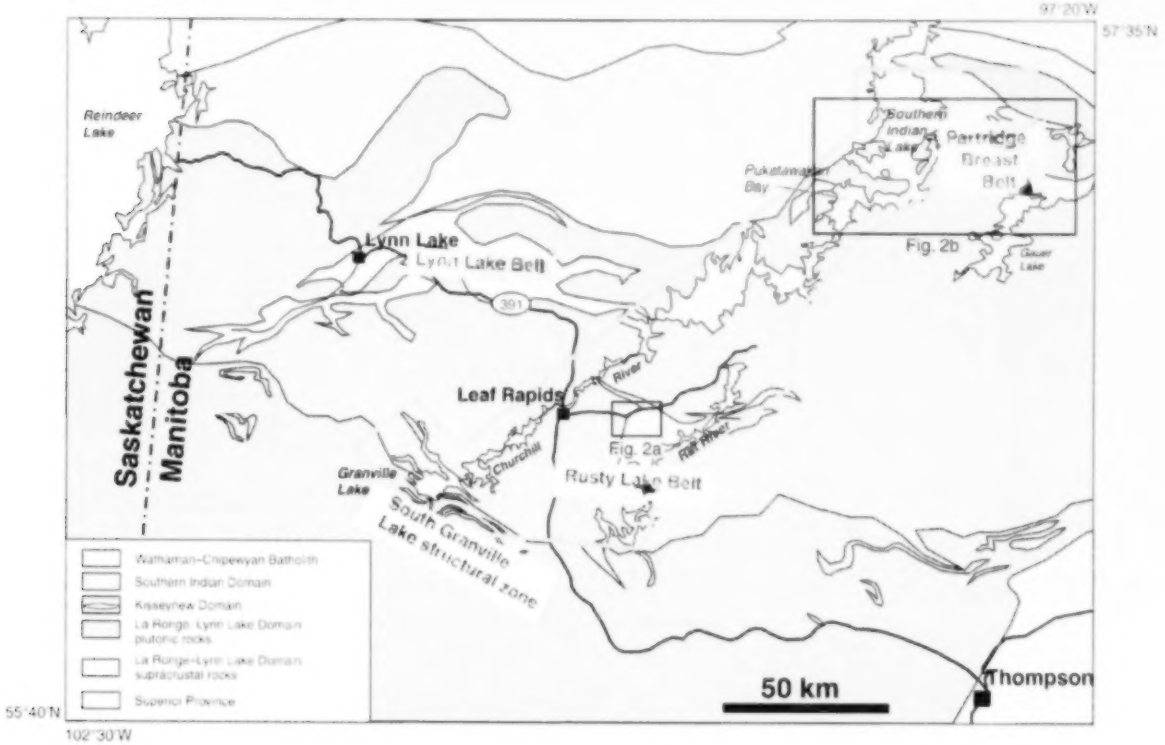

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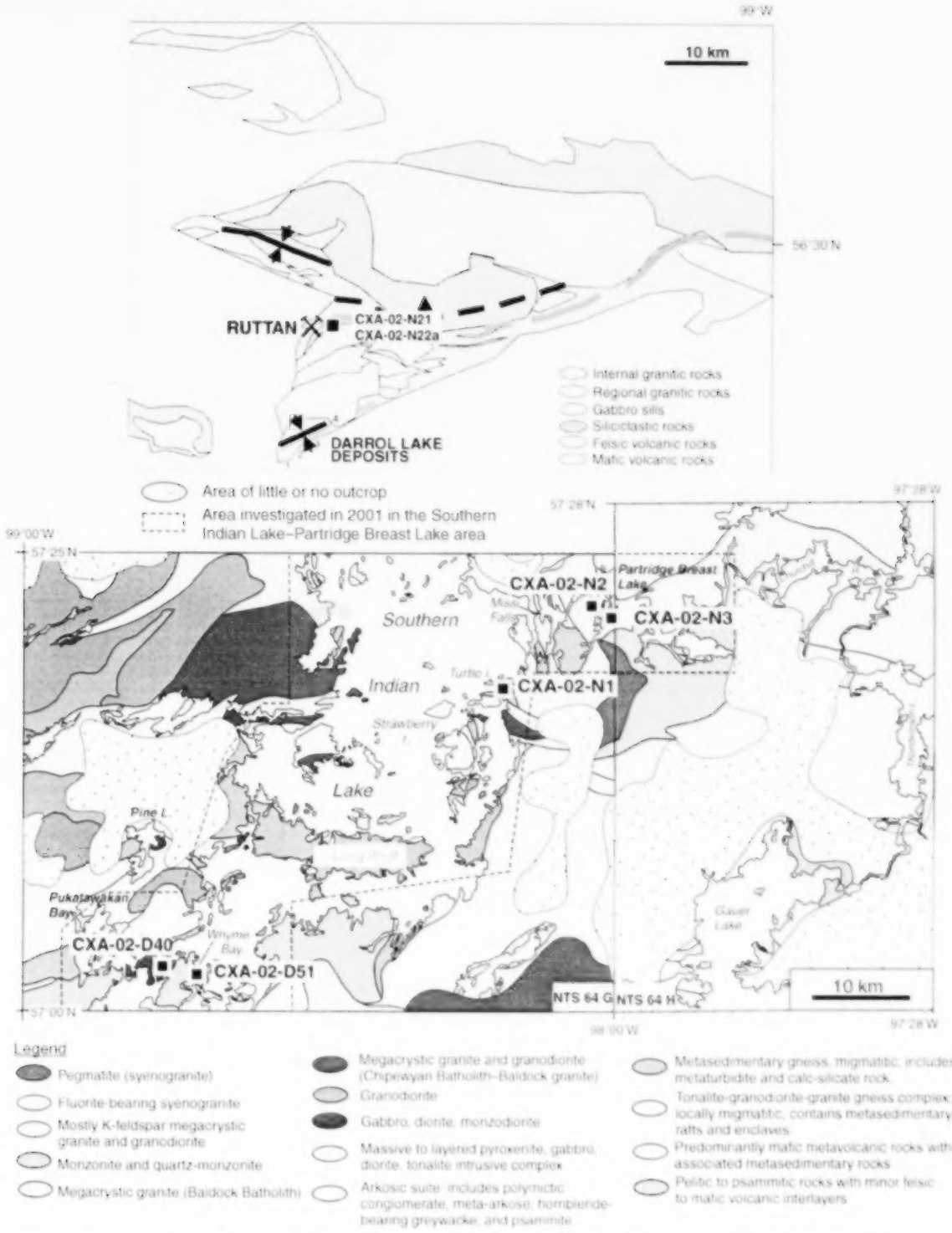

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rocks within the Southern Indian Domain. Geologically, it can be subdivided into the following three rock associations of different composition and age: 1) the Missi Falls gneiss association; 2) mafic volcanic rocks with minor intermediate and felsic components, associated with clastic sedimentary rocks; and 3) plutons that intrude the Missi Falls gneiss association and Partridge Breast Belt supracrustal rocks (Corrigan et al., 2002). To the north, supracrustal rocks of the Southern Indian Domain are intruded by the Chipewyan Batholith, equivalent to the Wathaman Batholith in Saskatchewan.

ANALYTICAL PROCEDURES

Ages were determined from a total of seven samples, four using the thermal ionization mass spectrometry (TIMS) technique and three using the Sensitive High Resolution Ion Microprobe (SHRIMP) at the Geological Survey of Canada.

Heavy minerals were separated from the rock samples by standard crushing, grinding, and heavy liquid techniques, then were sorted using a Frantz isodynamic separator. Samples analyzed by TIMS were heavily abraded before being submitted for U-Pb chemistry. Dissolution in concentrated HF, extraction of U and Pb, and mass spectrometry followed the methods described by Parrish et al. (1987). Analytical blanks for Pb were 2 to 5 pg. Results are presented in Table 1.

SHRIMP analytical procedure and U-Pb calibration details are given in Stern (1997) and Stern and Amelin (2003). The internal features of the zircons (zoning, structures, alteration, etc.) were characterized with backscattered electrons using a Cambridge Instruments scanning electron microscope. Prior to analysis, mount surfaces were evaporatively coated with 10 nm of high-purity gold. For the detrital zircon portion of this study, a 17 x 23 µm spot was used, with an O^- primary beam strength of 13 nA, operating at a mass resolution of 5350. A second phase of SHRIMP study involved dating a complex igneous body. In this phase, two spot sizes were used. A 26 µm x 36 µm spot with an O^- beam strength of 11 nA was used to target large, low-U domains. A smaller 13 µm x 16 µm spot (3.3 nA) was used to analyse thin, high-U rims. For both phases of the study, the count rates of ten isotopes of Zr^+, U^+, Th^+, and Pb^+ in zircon were sequentially measured (four scans for the analysis of detrital zircon and six scans for the analysis of igneous zircon) with a single electron multiplier and a pulse-counting system with dead time of 24 ns. The 1σ external errors of $^{206}Pb/^{238}U$ ratios reported in Table 2 incorporate a ±1.0 % error in calibrating the standard zircon (Stern and Amelin, 2003). No fractionation correction was applied to the Pb-isotope data; common Pb correction used the measured $^{204}Pb/^{206}Pb$ and compositions modelled after Cumming and Richards (1975). Isoplot v. 2.49 (Ludwig, 2001) was used to generate concordia plots and calculate weighted means. All errors quoted in the text are given at 2σ uncertainty.

GEOCHRONOLOGY SAMPLES AND RESULTS

The samples were collected from a range of tectonostratigraphic settings and provide constraints on the age of volcanism and sedimentation in the Rusty Lake Belt, on the deposition of fluvial to littoral facies sediments in the Partridge Breast Belt, and on the emplacement of orthogneiss and plutonic rocks.

TIMS

CXA-01-N21 (z7033)

A quartz-porphyry rhyolite was collected from the Ruttan mine site (Fig. 2a, UTM 461379, 6259218) and is considered part of the upper felsic volcanic unit of Ames and Taylor (1996). This fine-grained rhyolite contains blue quartz eyes up to 4 mm in diameter. This sample provides additional age constraints on volcanism in the Rusty Lake Belt, with currently only one known age (1878 ± 3 Ma) from a rhyolite in the stratigraphically higher Karsakuwigamak block (Baldwin et al., 1987). Zircon recovery from the Ruttan rhyolite was excellent. Fractions were selected from the diamagnetic mineral separate. The zircons were generally clear, colourless, stubby prisms with an aspect ratio of 2:1 and very sharp terminations. Most grains were moderately to highly fractured but contained few inclusions. Four fractions, one concordant and three slightly discordant, yielded an upper intercept age of 1883 ± 2 Ma, interpreted as the age of crystallization (Fig. 3a). This age is slightly older than that obtained by Baldwin et al. (1987) from the Karsakuwigamak block and is consistent with its relative stratigraphic position.

CXA-01-D51 (z7034)

A sample of undeformed K-feldspar megacrystic monzogranite, megascopically indistinguishable from the 1.86 to 1.85 Ga Wathaman-Chipewyan Batholith, was collected from the west shore of Whyme Bay, Southern Indian Lake (Fig. 2b, UTM 517450, 6321100). The monzogranite contains rafts of folded arenite, historically linked to the Sickle Group (Frohlinger and Cranstone, 1972). The age of this unit constrains timing of plutonism and provides a maximum age of folding in the sedimentary rocks. Zircon recovery from the monzogranite was excellent. All fractions submitted for dating were picked from the diamagnetic separate. Zircon morphologies ranged continuously from equant and stubby prisms through to needles. All zircons were clear and colourless with few visible inclusions or fractures. Three concordant fractions and one slightly discordant fraction yielded a crystallization age of 1829 ± 1 Ma (Fig. 3b). This surprising result may indicate that the age range of the Wathaman Batholith is broader than previously known or that a separate igneous event produced plutons of similar composition. Pending results from whole-rock geochemical analysis may shed some light on this question.

Table 1. TIMS data.

Fraction	No. grains	Wt. (µg)	U^2 (ppm)	Th^m (ppm)	$\frac{Th^m}{U}$	Pb^{*2} (ppm)	Pb^{c1} (pg)	$\frac{^{206}Pb^1}{^{204}Pb}$	$\frac{^{208}Pb^2}{^{206}Pb}$	$\frac{^{207}Pb^2}{^{235}U}$	± $\frac{^{207}Pb}{^{235}U}$	$\frac{^{206}Pb^2}{^{238}U}$	± $\frac{^{206}Pb}{^{238}U}$	Corr Coeff	$\frac{^{207}Pb^2}{^{204}Pb}$	± $\frac{^{207}Pb}{^{204}Pb}$	Apparent Ages (Ma) $\frac{^{206}Pb}{^{238}U}$	± $\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{235}U}$	± $\frac{^{207}Pb}{^{235}U}$	$\frac{^{207}Pb}{^{206}Pb}$	± $\frac{^{207}Pb}{^{206}Pb}$	Disc. (%)
CXA-01-N21 Ruffan rhyolite (z7033)																							
A (Z)*	19	6	165	63	0.38	59	2	13651	0.11	5.34	0.0075	0.3358	0.00044	0.940313	0.11535	5.77E-05	1866.3	4.1	1875.3	2.5	1885	2.0	1.16
B (Z)	25	6	224	86	0.38	80	1	13299	0.11	5.394	0.0102	0.3397	0.00061	0.936741	0.11518	8.06E-05	1885.2	5.8	1884.0	3.2	1883	2.0	-0.16
C (Z)	32	9	136	128	0.94	48	1	18050	0.11	5.352	0.0075	0.3368	0.00040	0.941719	0.11526	5.76E-05	1871.1	3.8	1877.2	2.3	1884	2.0	0.79
D (Z)	36	10	238	96	0.40	85	3	13764	0.12	5.32	0.0090	0.3347	0.00050	0.952634	0.11528	5.76E-05	1861.1	4.9	1872.0	2.8	1884	2.0	1.42
CXA-01-D51 megacrystic monzogranite (z7034)																							
A (Z)	4	10	233	72	0.31	79	5	9262	0.09	5.056	0.0076	0.3281	0.00043	0.940361	0.11176	5.59E-05	1829.1	4.1	1828.7	2.5	1828	2.0	-0.05
A2 (Z)	3	11	131	43	0.33	45	6	4865	0.1	5.043	0.0066	0.3271	0.00036	0.899167	0.11182	6.71E-05	1824.2	3.5	1826.5	2.3	1829	2.0	0.31
B (Z)	11	8	150	48	0.32	51	4	6736	0.09	5.03	0.0075	0.3263	0.00042	0.95136	0.1118	5.59E-05	1820.3	4.2	1824.3	2.6	1829	2.0	0.54
D1 (Z)	1	8	192	77	0.40	66	9	3124	0.12	5.046	0.0071	0.3273	0.00036	0.910557	0.11182	6.71E-05	1825.1	3.6	1827.0	2.4	1829	2.0	0.25
CXA-01-D40 monzodiorite (z7036)																							
A1 (Z)	9	12	471	132	0.28	159	7	16714	0.08	5.074	0.0203	0.3291	0.00128	0.994324	0.11182	4.47E-05	1834	12.4	1831.7	6.7	1829	2.0	-0.3
B1 (Z)	7	8	301	99	0.33	102	3	18180	0.1	5.031	0.0060	0.3265	0.00033	0.944539	0.11173	4.47E-05	1821.6	3.2	1824.5	5.2	1828	2.0	0.39
C1 (Z)	7	10	371	101	0.27	124	2	40145	0.08	5.048	0.0076	0.3275	0.00043	0.951916	0.11177	5.59E-05	1826.5	4.2	1827.4	2.5	1828	2.0	0.12
D1 (Z)	3	9	593	297	0.50	209	2	32805	0.15	5.022	0.0065	0.326	0.00036	0.951951	0.11173	4.47E-05	1819.1	3.5	1823.1	2.2	1828	2.0	0.54
CXA-01-N2 Missi Falls monzogranite (z7032)																							
A2 (Z)	21	7	1517	406	0.27	516	29	7041	0.08	5.237	0.0073	0.332	0.00040	0.949504	0.1144	5.72E-05	1848	3.8	1858.6	2.4	1871	2.0	1.38
B2 (Z)	5	1	1116	309	0.28	378	18	1394	0.08	5.13	0.0077	0.3297	0.00033	0.794824	0.11287	0.000102	1836.7	3.3	1841.1	2.6	1846	3.0	0.59
B3 (Z)	4	1	1410	520	0.37	483	7	5421	0.11	5.074	0.0066	0.3265	0.00036	0.89666	0.11271	6.76E-05	1821.6	3.4	1831.8	2.2	1844	2.0	1.37
B4 (Z)	1	1	1210	363	0.30	422	3	4534	0.09	5.394	0.0065	0.3372	0.00034	0.913471	0.11601	5.8E-05	1873.3	3.1	1883.9	2.1	1896	2.0	1.36
M1 (M)	1	1	10710	107528	10.04	12124	3	65126	2.92	4.968	0.0060	0.3244	0.00029	0.947699	0.11108	4.44E-05	1811.1	2.9	1813.9	2.0	1817	2.0	0.38
M2 (M)	1	2	13066	165285	12.65	17726	9	56777	3.68	5.046	0.0061	0.3272	0.00029	0.94895	0.11186	4.47E-05	1824.7	3	1827.1	2.0	1830	2.0	0.32
M3 (M)	1	4	768	37647	49.02	3381	4	18476	14.24	5.138	0.0062	0.3309	0.00033	0.918166	0.11263	5.63E-05	1842.7	3.2	1842.5	2.0	1842	2.0	-0.03

1 SE % on ratios
2 SE Ma on ages
* (Z) = zircon, (M) = monazite
1 = spike and fractionation corrected only
2 = spike, fractionation and blank corrected
m = model value calculated from assuming concordance between the $^{232}Th/^{208}Pb$ and $^{238}U/^{206}Pb$.
Blank composition $^{206}Pb/^{204}Pb = 18.2$, $^{207}Pb/^{204}Pb = 15.37$, $^{208}Pb/^{204}Pb = 37.8$

Table 2. SHRIMP data.

Fraction	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb	± ^{204}Pb/^{206}Pb	f(206)^{204}	^{208}Pb*/^{206}Pb*	± ^{208}Pb*/^{206}Pb*	^{207}Pb*/^{235}U	± ^{207}Pb*/^{235}U	^{206}Pb*/^{238}U	± ^{206}Pb*/^{238}U	Corr Coeff	Apparent Ages (Ma) ^{207}Pb*/^{206}Pb*	± ^{207}Pb*/^{206}Pb*	^{206}Pb*/^{238}U	± ^{206}Pb*/^{238}U	^{207}Pb*/^{206}Pb*	± ^{207}Pb*/^{206}Pb*	Disc. (%)
CXA-01-N1 Turtle Island quartz diorite																						
7031-49.2	1030	21	0.02	289	6	2.51E-05	1.29E-05	0.00044	0.00566	0.00063	4.374	0.055	0.29238	0.00323	0.9297	0.10849	0.00050	1653	16	1774	8	6.8
7031-28.2	99	51	0.53	36	4	1.25E-04	4.83E-05	0.00216	0.14757	0.00614	5.241	0.144	0.33784	0.00473	0.6085	0.11252	0.00248	1876	23	1840	40	-1.9
7031-51.1	208	63	0.32	70	11	1.80E-04	6.58E-05	0.00312	0.08277	0.00374	5.105	0.092	0.32813	0.00406	0.7684	0.11284	0.00131	1829	20	1846	21	0.9
7031-27.1	41	15	0.38	14	4	3.51E-04	1.00E-04	0.00608	0.10549	0.00531	5.002	0.133	0.32037	0.00571	0.7556	0.11323	0.00198	1792	28	1852	32	3.3
7031-22.1	103	43	0.43	37	4	1.18E-04	4.10E-05	0.00204	0.12306	0.00642	5.317	0.090	0.33726	0.00456	0.8654	0.11435	0.00097	1874	22	1870	15	-0.2
7031-22.2	134	62	0.48	49	1	2.57E-05	2.36E-05	0.00045	0.14484	0.00265	5.397	0.126	0.34096	0.00738	0.9604	0.11480	0.00075	1891	36	1877	12	-0.8
7031-28.1	367	214	0.60	137	4	3.59E-05	1.46E-05	0.00062	0.17446	0.00366	5.351	0.071	0.33635	0.00388	0.9196	0.11537	0.00061	1869	19	1886	9	0.9
7031-56.2	152	49	0.33	53	8	1.78E-04	5.84E-05	0.00309	0.09232	0.00542	5.371	0.102	0.33551	0.00442	0.7713	0.11610	0.00142	1865	21	1897	22	1.7
7031-24.1	140	86	0.64	54	1	1.36E-05	3.39E-05	0.00024	0.18791	0.00467	5.439	0.092	0.33945	0.00489	0.9046	0.11622	0.00084	1884	24	1899	13	0.8
7031-36.1	144	76	0.55	53	3	6.21E-05	2.79E-05	0.00108	0.15756	0.00252	5.347	0.087	0.33310	0.00444	0.8798	0.11642	0.00091	1853	21	1902	14	2.6
7031-21.1	61	22	0.36	22	1	7.97E-05	6.46E-05	0.00138	0.10818	0.00415	5.478	0.116	0.34101	0.00557	0.8382	0.11651	0.00136	1892	27	1903	21	0.6
7031-31.1	161	101	0.65	60	2	3.77E-05	3.75E-05	0.00065	0.18822	0.00292	5.348	0.081	0.33281	0.00414	0.8822	0.11655	0.00084	1852	20	1904	13	2.7
7031-41.1	91	73	0.82	36	0	1.00E-05	1.00E-05	0.00017	0.23718	0.00985	5.383	0.142	0.33432	0.00592	0.7536	0.11678	0.00204	1859	29	1908	32	2.5
7031-49.1	90	41	0.46	32	3	1.12E-04	3.94E-05	0.00195	0.13165	0.00321	5.314	0.114	0.32884	0.00516	0.8078	0.11720	0.00149	1833	25	1914	23	4.2
7031-43.2	355	105	0.31	125	13	1.26E-04	6.59E-05	0.00219	0.09732	0.00340	5.469	0.112	0.33697	0.00450	0.7366	0.11772	0.00164	1872	22	1922	25	2.6
7031-53.2	380	209	0.57	134	5	5.19E-05	3.31E-05	0.00090	0.15733	0.00538	5.209	0.077	0.32026	0.00380	0.8677	0.11796	0.00087	1791	19	1926	13	7
7031-33.1	306	369	1.25	138	1	7.12E-06	1.17E-05	0.00012	0.35594	0.00416	5.928	0.079	0.35342	0.00416	0.9305	0.12166	0.00060	1951	20	1981	9	1.5
7031-53.1	85	59	0.72	36	3	1.09E-04	3.97E-05	0.00189	0.19816	0.00375	6.617	0.134	0.37064	0.00626	0.8912	0.12947	0.00120	2032	29	2091	16	2.8
7031-50.1	263	92	0.36	101	3	3.41E-05	2.04E-05	0.00059	0.09861	0.00159	6.522	0.096	0.36464	0.00483	0.9444	0.12971	0.00063	2004	23	2094	9	4.3
7031-32.1	214	132	0.64	104	3	4.08E-05	2.18E-05	0.00071	0.17627	0.00212	8.674	0.116	0.42846	0.00498	0.9208	0.14682	0.00077	2299	23	2309	9	0.5
7031-34.1	334	129	0.40	145	5	4.11E-05	1.94E-05	0.00071	0.10535	0.00396	8.139	0.109	0.40182	0.00456	0.9029	0.14690	0.00085	2177	21	2310	10	5.7
7031-50.2	181	63	0.36	85	3	4.16E-05	2.84E-05	0.00072	0.09937	0.00189	8.921	0.165	0.43812	0.00746	0.9594	0.14768	0.00077	2342	34	2319	9	-1
7031-35.2	389	185	0.49	174	11	7.86E-05	2.35E-05	0.00136	0.14204	0.00293	8.285	0.109	0.40361	0.00458	0.9156	0.14888	0.00079	2186	21	2333	9	6.3
7031-35.1	180	136	0.78	91	2	2.67E-05	1.96E-05	0.00046	0.21885	0.00268	8.866	0.133	0.42768	0.00541	0.8987	0.15035	0.00100	2295	24	2350	11	2.3
7031-4.1	95	44	0.48	48	4	1.02E-04	4.02E-05	0.00177	0.12964	0.00445	9.578	0.190	0.45450	0.00692	0.8365	0.15284	0.00167	2415	31	2378	19	-1.6
7031-47.1	53	34	0.66	26	2	8.28E-05	6.12E-05	0.00144	0.17598	0.00446	9.156	0.172	0.43149	0.00664	0.8790	0.15390	0.00139	2312	30	2390	15	3.2
7031-56.1	197	121	0.64	100	3	3.82E-05	3.02E-05	0.00066	0.18076	0.00242	9.359	0.138	0.43996	0.00544	0.8941	0.15429	0.00103	2350	24	2394	11	1.8
7031-20.1	287	167	0.60	146	9	8.61E-05	1.89E-05	0.00149	0.16743	0.00178	9.577	0.124	0.44770	0.00497	0.9110	0.15514	0.00083	2385	22	2403	9	0.8
7031-13.1	91	38	0.43	44	2	5.17E-05	3.59E-05	0.00090	0.12064	0.00302	9.360	0.150	0.43751	0.00615	0.9234	0.15517	0.00096	2340	28	2404	11	2.7
7031-17.1	222	120	0.56	114	3	3.36E-05	1.54E-05	0.00058	0.15653	0.00197	10.141	0.153	0.45481	0.00552	0.8678	0.16171	0.00122	2417	25	2474	13	2.3
7031-40.1	453	217	0.49	239	1	3.77E-06	7.85E-06	0.00007	0.14035	0.00130	10.609	0.139	0.46974	0.00550	0.9362	0.16380	0.00076	2482	24	2495	8	0.5
7031-43.1	164	77	0.48	85	3	4.63E-05	1.91E-05	0.00080	0.13593	0.00201	10.534	0.171	0.46369	0.00667	0.9306	0.16476	0.00099	2456	29	2505	10	2

Notes (*see* Stern, 1997):
Uncertainties reported at 1σ (*absolute*) and are calculated by numerical propagation of all known sources of error
f206^{204} refers to mole fraction of total ^{206}Pb that is due to common Pb, calculated using the ^{204}Pb method; common Pb composition used is the surface blank
Discordance relative to origin = 100 * (1-(^{206}Pb/^{238}U age)/(^{207}Pb/^{206}Pb age))
* = radiogenic Pb

Table 2. (cont.)

Fraction	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb	± ^{204}Pb/^{206}Pb	f(206)^{204}	^{208*}Pb/^{206*}Pb	± ^{208}Pb/^{206}Pb	^{207*}Pb/^{235}U	± ^{207}Pb/^{235}U	^{206*}Pb/^{238}U	± ^{206}Pb/^{238}U	Corr Coeff	Apparent Ages (Ma) ^{207*}Pb/^{206*}Pb	± ^{207}Pb/^{206}Pb	^{206}Pb/^{238}U	± ^{206}Pb/^{238}U	^{207}Pb/^{206}Pb	± ^{207}Pb/^{206}Pb	Disc. (%)
7031-60.1	86	62	0.75	47	1	2.48E-05	5.53E-05	0.00043	0.20792	0.00387	10.525	0.183	0.46046	0.00646	0.8695	0.16578	0.00143	2442	29	2516	15	2.9
CXA-01-N22A Powder Magazine formation																						
7030-111.1	61	93	1.57	27	0	1.00E-05	1.00E-05	0.00017	0.47016	0.02192	4.995	0.121	0.32528	0.00621	0.8533	0.11137	0.00142	1815	30	1822	23	0.4
7030-159.1	112	38	0.35	39	2	5.40E-05	2.99E-05	0.00094	0.10284	0.00376	5.187	0.098	0.33367	0.00477	0.8282	0.11274	0.00120	1856	23	1844	19	-0.7
7030-222.1	249	138	0.57	91	1	1.00E-05	1.00E-05	0.00017	0.16702	0.00285	5.174	0.087	0.33073	0.00462	0.8855	0.11345	0.00090	1842	22	1855	14	0.7
7030-145.1	169	44	0.27	58	1	1.40E-05	3.48E-05	0.00024	0.07964	0.00259	5.262	0.090	0.33588	0.00445	0.8453	0.11363	0.00104	1867	22	1858	17	-0.5
7030-248.1	122	52	0.44	44	0	1.00E-05	1.00E-05	0.00017	0.13181	0.00708	5.326	0.134	0.33693	0.00745	0.9220	0.11398	0.00112	1882	36	1864	18	-1
7030-264.1	292	128	0.45	108	0	3.82E-06	1.26E-05	0.00007	0.13306	0.00281	5.432	0.078	0.34549	0.00423	0.9070	0.11404	0.00069	1913	20	1865	11	-2.6
7030-212.1	147	53	0.38	51	1	3.31E-05	1.49E-05	0.00057	0.11027	0.00298	5.234	0.087	0.33283	0.00431	0.8462	0.11405	0.00102	1852	21	1865	16	0.7
7030-255.1	213	68	0.33	75	1	1.00E-05	1.00E-05	0.00017	0.09915	0.00252	5.291	0.090	0.33548	0.00428	0.8199	0.11438	0.00112	1865	21	1870	18	0.3
7030-260.1	254	95	0.39	88	1	1.00E-05	1.00E-05	0.00017	0.11458	0.00228	5.185	0.076	0.32834	0.00399	0.8833	0.11454	0.00080	1830	19	1873	13	2.3
7030-269.1	163	67	0.42	58	0	1.00E-05	1.00E-05	0.00017	0.12663	0.00644	5.287	0.100	0.33479	0.00531	0.8949	0.11454	0.00097	1862	26	1873	15	0.6
7030-204.1	254	99	0.40	91	1	1.00E-05	1.00E-05	0.00017	0.11687	0.00493	5.329	0.079	0.33735	0.00406	0.8776	0.11457	0.00082	1874	20	1873	13	0
7030-132.1	126	47	0.39	45	0	1.00E-05	1.00E-05	0.00017	0.11474	0.00364	5.392	0.092	0.34106	0.00460	0.8526	0.11467	0.00104	1892	22	1875	16	-0.9
7030-268.1	499	187	0.39	175	1	1.00E-05	1.00E-05	0.00017	0.11422	0.00167	5.255	0.069	0.33223	0.00362	0.9245	0.11473	0.00058	1849	19	1876	9	1.4
7030-206.1	827	601	0.75	322	2	1.00E-05	1.00E-05	0.00017	0.21903	0.00207	5.360	0.067	0.33862	0.00368	0.9236	0.11479	0.00055	1880	18	1877	9	-0.2
7030-123.1	157	54	0.35	56	0	1.00E-05	1.00E-05	0.00017	0.10684	0.00267	5.329	0.105	0.33649	0.00489	0.8109	0.11486	0.00134	1870	24	1878	21	0.4
7030-244.1	179	55	0.32	63	1	1.00E-05	1.00E-05	0.00017	0.09411	0.00278	5.373	0.085	0.33892	0.00423	0.8567	0.11498	0.00094	1881	20	1880	15	-0.1
7030-250.1	263	111	0.44	94	1	8.77E-06	9.26E-06	0.00015	0.12429	0.00310	5.327	0.088	0.33583	0.00488	0.9234	0.11503	0.00074	1867	24	1880	12	0.7
7030-253.1	222	54	0.25	76	2	3.34E-05	2.64E-05	0.00058	0.07683	0.00281	5.286	0.083	0.33317	0.00413	0.8566	0.11511	0.00094	1854	20	1882	15	1.5
7030-185.1	125	50	0.41	44	0	1.00E-05	1.00E-05	0.00017	0.11897	0.00607	5.255	0.093	0.33097	0.00422	0.7995	0.11517	0.00123	1843	20	1882	19	2.1
7030-216.1	238	69	0.30	81	1	1.36E-05	1.94E-05	0.00024	0.08515	0.00212	5.256	0.076	0.33103	0.00396	0.8811	0.11517	0.00080	1843	19	1883	13	2.1
7030-120.1	295	174	0.61	108	1	1.00E-05	1.00E-05	0.00017	0.17642	0.00256	5.217	0.070	0.32823	0.00391	0.9319	0.11527	0.00057	1830	19	1884	9	2.9
7030-161.1	245	100	0.42	88	1	1.36E-05	1.55E-05	0.00024	0.11730	0.00232	5.396	0.075	0.33937	0.00399	0.9026	0.11533	0.00069	1884	19	1885	11	0.1
7030-236.1	50	11	0.24	16	0	1.61E-05	8.74E-05	0.00028	0.06887	0.00560	5.177	0.223	0.32543	0.01215	0.9179	0.11537	0.00198	1816	59	1886	31	3.7
7030-266.1	693	273	0.41	252	1	3.82E-06	4.70E-06	0.00007	0.11979	0.00141	5.443	0.065	0.34175	0.00370	0.9430	0.11551	0.00047	1895	18	1888	7	-0.4
7030-152.1	143	42	0.31	49	2	5.61E-05	4.81E-05	0.00097	0.08649	0.00565	5.266	0.100	0.33051	0.00497	0.8543	0.11556	0.00116	1841	24	1889	18	2.5
7030-168.1	785	364	0.48	292	1	2.87E-06	7.46E-06	0.00005	0.14236	0.00165	5.462	0.065	0.34394	0.00367	0.9453	0.11560	0.00045	1906	18	1889	7	-0.9
7030-130.1	2593	3215	1.28	1139	0	3.60E-07	1.66E-06	0.00001	0.37043	0.00635	5.479	0.087	0.34319	0.00443	0.8755	0.11579	0.00089	1902	21	1892	14	-0.5
7030-233.1	358	114	0.33	122	1	1.01E-05	1.02E-05	0.00018	0.10455	0.00339	5.184	0.072	0.32458	0.00370	0.8822	0.11583	0.00076	1812	18	1893	12	4.3
7030-207.1	280	109	0.40	98	2	2.17E-05	1.14E-05	0.00038	0.11683	0.00222	5.277	0.104	0.32948	0.00596	0.9572	0.11616	0.00067	1836	29	1898	10	3.3
7030-263.1	105	28	0.28	36	1	2.39E-05	3.74E-05	0.00041	0.08304	0.00359	5.393	0.156	0.33576	0.00857	0.9277	0.11650	0.00127	1866	42	1903	20	1.9

Notes (*see* Stern, 1997):
Uncertainties reported at 1σ (absolute) and are calculated by numerical propagation of all known sources of error
f206^{204} refers to mole fraction of total ^{206}Pb that is due to common Pb, calculated using the ^{204}Pb method; common Pb composition used is the surface blank
Discordance relative to origin = 100 * (1-(^{206}Pb/^{238}U age)/(^{207}Pb/^{206}Pb age))
* = radiogenic Pb

Table 2. (cont.)

Fraction	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	^{204}Pb (ppb)	^{204}Pb/^{206}Pb	± ^{204}Pb/^{206}Pb	f(206)^{204}	^{208*}Pb/^{206*}Pb	± ^{208}Pb/^{206}Pb	^{207*}Pb/^{235}U	± ^{207}Pb/^{235}U	^{206*}Pb/^{238}U	± ^{206}Pb/^{238}U	Corr Coeff	Apparent Ages (Ma) ^{207*}Pb/^{206*}Pb	± ^{207}Pb/^{206}Pb	^{206}Pb/^{238}U	± ^{206}Pb/^{238}U	^{207}Pb/^{206}Pb	± ^{207}Pb/^{206}Pb	Disc. (%)
7030-202.1	242	80	0.34	85	1	1.00E-05	1.00E-05	0.00017	0.09323	0.00277	5.426	0.129	0.33696	0.00688	0.9125	0.11678	0.00114	1872	33	1908	18	1.9
7030-226.1	107	28	0.27	36	0	4.02E-06	4.99E-05	0.00007	0.08203	0.00427	5.344	0.105	0.33049	0.00476	0.8089	0.11727	0.00136	1841	23	1915	21	3.9
7030-245.1	222	111	0.52	81	0	5.62E-06	1.05E-05	0.00010	0.14990	0.00586	5.429	0.084	0.33578	0.00425	0.8800	0.11728	0.00087	1866	21	1915	13	2.5
7030-271.1	310	120	0.40	108	0	1.28E-06	8.18E-06	0.00002	0.11371	0.00209	5.337	0.078	0.32983	0.00391	0.8683	0.11736	0.00086	1838	19	1916	13	4.1
7030-234.1	278	96	0.36	97	3	3.27E-05	1.52E-05	0.00057	0.10470	0.00233	5.355	0.084	0.33036	0.00415	0.8631	0.11756	0.00094	1840	20	1919	14	4.1
7030-241.1	183	57	0.32	63	0	7.55E-06	2.30E-05	0.00013	0.09465	0.00319	5.340	0.089	0.32849	0.00442	0.8663	0.11790	0.00099	1831	21	1925	15	4.9
CXA-01-N3 Partridge Breast conglomerate																						
7029-232.1	528	437	0.85	211	3	1.69E-05	8.84E-06	0.00029	0.25061	0.00247	5.301	0.073	0.33936	0.00384	0.8762	0.11328	0.00076	1884	18	1853	12	-1.7
7029-281.1	247	180	0.75	96	1	1.00E-05	1.00E-05	0.00017	0.22064	0.00682	5.277	0.089	0.33699	0.00437	0.8407	0.11356	0.00104	1872	21	1857	17	-0.8
7029-276.1	320	169	0.54	119	1	1.00E-05	1.00E-05	0.00017	0.15906	0.00237	5.322	0.081	0.33959	0.00399	0.8437	0.11366	0.00093	1885	19	1859	15	-1.4
7029-270.1	236	189	0.83	92	2	2.68E-05	2.36E-05	0.00046	0.24729	0.00453	5.229	0.100	0.33233	0.00472	0.8141	0.11412	0.00128	1850	23	1866	20	0.9
7029-136.1	553	297	0.56	205	2	1.00E-05	1.00E-05	0.00017	0.16223	0.00187	5.311	0.071	0.33725	0.00391	0.9185	0.11421	0.00061	1873	19	1867	10	-0.3
7029-143.1	597	347	0.60	225	2	1.00E-05	1.00E-05	0.00017	0.17408	0.00198	5.355	0.087	0.33934	0.00373	0.7576	0.11444	0.00123	1884	18	1871	19	-0.7
7029-151.1	522	374	0.74	206	0	8.10E-07	7.02E-06	0.00001	0.22366	0.00240	5.408	0.105	0.34241	0.00396	0.6879	0.11456	0.00163	1898	19	1873	26	-1.4
7029-249.1	860	508	0.61	323	2	8.76E-06	4.39E-06	0.00015	0.17825	0.00165	5.328	0.066	0.33729	0.00370	0.9292	0.11457	0.00053	1874	18	1873	8	0
7029-292.1	319	168	0.54	117	1	1.00E-05	1.00E-05	0.00017	0.16359	0.00283	5.280	0.105	0.33420	0.00494	0.8150	0.11458	0.00133	1859	24	1873	21	0.8
7029-106.1	226	106	0.48	83	1	1.00E-05	1.00E-05	0.00017	0.14526	0.00267	5.343	0.084	0.33805	0.00451	0.9010	0.11463	0.00079	1877	22	1874	12	-0.2
7029-205.1	793	434	0.57	287	2	1.00E-05	1.00E-05	0.00017	0.16438	0.00169	5.197	0.066	0.32859	0.00363	0.9166	0.11470	0.00059	1832	18	1875	9	2.3
7029-266.1	379	236	0.64	142	1	1.00E-05	1.00E-05	0.00017	0.18722	0.00277	5.293	0.076	0.33458	0.00394	0.8812	0.11474	0.00078	1861	19	1876	12	0.8
7029-101.1	270	186	0.71	103	1	1.00E-05	1.00E-05	0.00017	0.20773	0.00312	5.326	0.077	0.33650	0.00415	0.9093	0.11479	0.00069	1870	20	1877	11	0.4
7029-218.1	353	209	0.61	130	0	3.43E-06	1.12E-05	0.00006	0.17740	0.00245	5.252	0.077	0.33136	0.00383	0.8550	0.11496	0.00088	1845	19	1879	14	1.8
7029-268.1	998	725	0.75	381	9	3.22E-05	8.62E-06	0.00056	0.22778	0.00370	5.242	0.107	0.33047	0.00356	0.6254	0.11505	0.00185	1841	17	1881	29	2.1
7029-115.1	920	548	0.62	342	3	1.00E-05	1.00E-05	0.00017	0.18214	0.00170	5.281	0.079	0.33290	0.00412	0.8845	0.11506	0.00081	1852	20	1881	13	1.5
7029-286.1	244	82	0.35	84	1	1.00E-05	1.00E-05	0.00017	0.10605	0.00321	5.225	0.074	0.32922	0.00388	0.8900	0.11511	0.00075	1835	19	1882	12	2.5
7029-296.1	495	331	0.69	189	1	1.00E-05	1.00E-05	0.00017	0.20509	0.00259	5.342	0.076	0.33623	0.00392	0.8770	0.11522	0.00080	1869	19	1883	13	0.8
7029-236.1	368	197	0.55	134	1	8.02E-06	1.20E-05	0.00014	0.15963	0.00260	5.274	0.067	0.33191	0.00365	0.9182	0.11524	0.00058	1848	18	1884	9	1.9
7029-148.1	440	177	0.42	161	3	2.13E-05	8.18E-06	0.00037	0.12451	0.00203	5.456	0.072	0.34323	0.00401	0.9294	0.11528	0.00057	1902	19	1884	9	-1
7029-216.1	287	217	0.78	109	1	1.00E-05	1.00E-05	0.00017	0.23131	0.00312	5.209	0.070	0.32767	0.00376	0.9065	0.11529	0.00066	1827	18	1884	10	3
7029-291.1	286	188	0.68	110	1	1.00E-05	1.00E-05	0.00017	0.20002	0.00284	5.394	0.081	0.33913	0.00408	0.8630	0.11535	0.00088	1882	20	1885	14	0.2
7029-298.1	243	60	0.26	83	0	6.19E-06	1.75E-05	0.00011	0.07329	0.00191	5.344	0.077	0.33559	0.00402	0.8941	0.11549	0.00075	1865	19	1888	12	1.2
7029-302.1	138	74	0.55	50	0	1.00E-05	1.00E-05	0.00017	0.16680	0.00459	5.235	0.099	0.32845	0.00490	0.8564	0.11560	0.00113	1831	24	1889	18	3.1
7029-227.1	1864	1975	1.09	763	2	4.07E-06	4.55E-06	0.00007	0.30987	0.00193	5.313	0.067	0.33329	0.00370	0.9300	0.11562	0.00054	1854	18	1890	8	1.9

Notes (*see* Stern, 1997):
Uncertainties reported at 1σ (absolute) and are calculated by numerical propagation of all known sources of error
f206^{204} refers to mole fraction of total ^{206}Pb that is due to common Pb, calculated using the ^{204}Pb method; common Pb composition used is the surface blank
Discordance relative to origin = 100 * (1-(^{206}Pb/^{238}U age)/(^{207}Pb/^{206}Pb age))
* = radiogenic Pb

Table 2. (cont.)

Fraction	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	^{204}Pb (ppb)	$^{204}Pb/^{206}Pb$	$\pm\ ^{204}Pb/^{206}Pb$	$f(206)^{204}$	$^{208*}Pb/^{206*}Pb$	$\pm\ ^{208}Pb/^{206}Pb$	$^{207*}Pb/^{235}U$	$\pm\ ^{207}Pb/^{235}U$	$^{206*}Pb/^{238}U$	$\pm\ ^{206}Pb/^{238}U$	Corr Coeff	Apparent Ages (Ma)						Disc. (%)
																$^{207*}Pb/^{206*}Pb$	$\pm\ ^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$	$\pm\ ^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	$\pm\ ^{207}Pb/^{206}Pb$	
7029-245.1	452	259	0.59	167	1	1.00E-05	1.00E-05	0.00017	0.17078	0.00211	5.317	0.072	0.33335	0.00377	0.8913	0.11568	0.00072	1855	18	1890	11	1.9
7029-148.2	128	40	0.32	46	0	1.00E-05	1.00E-05	0.00017	0.09696	0.00292	5.496	0.096	0.34427	0.00462	0.8401	0.11579	0.00110	1907	22	1892	17	-0.8
7029-300.1	795	438	0.57	296	2	1.00E-05	1.00E-05	0.00017	0.16808	0.00267	5.374	0.067	0.33641	0.00361	0.9094	0.11586	0.00061	1869	17	1893	9	1.3
7029-207.1	1893	1125	0.61	727	6	1.00E-05	1.00E-05	0.00017	0.17823	0.00111	5.513	0.069	0.34496	0.00395	0.9549	0.11590	0.00043	1911	19	1894	7	-0.9
7029-285.1	301	158	0.54	113	1	1.13E-05	1.16E-05	0.00020	0.15521	0.00406	5.487	0.083	0.34287	0.00416	0.8652	0.11606	0.00089	1900	20	1896	14	-0.2
7029-303.1	297	206	0.72	114	2	1.82E-05	2.23E-05	0.00032	0.21177	0.00341	5.380	0.088	0.33616	0.00447	0.8751	0.11608	0.00092	1868	22	1897	14	1.5
7029-121.1	469	176	0.39	166	44	3.28E-04	2.93E-05	0.00569	0.12227	0.00252	5.327	0.075	0.33266	0.00380	0.8705	0.11614	0.00081	1851	18	1898	13	2.4
7029-248.1	1154	506	0.45	425	3	1.00E-05	1.00E-05	0.00017	0.13161	0.00138	5.493	0.069	0.34290	0.00373	0.9193	0.11618	0.00058	1901	18	1898	9	-0.1
7029-280.1	341	196	0.59	125	1	1.00E-05	1.00E-05	0.00017	0.17383	0.00246	5.310	0.083	0.33120	0.00427	0.8830	0.11628	0.00086	1844	21	1900	13	2.9
7029-279.1	752	456	0.63	281	0	5.00E-08	1.32E-05	0.00000	0.18542	0.00178	5.357	0.069	0.33389	0.00360	0.8924	0.11637	0.00068	1857	17	1901	11	2.3
7029-163.1	232	132	0.59	90	1	1.00E-05	1.00E-05	0.00017	0.17465	0.00791	5.632	0.111	0.35046	0.00514	0.8164	0.11656	0.00134	1937	25	1904	21	-1.7
7029-116.1	101	28	0.29	35	0	7.88E-06	4.60E-05	0.00014	0.08982	0.00908	5.400	0.107	0.33555	0.00484	0.8008	0.11672	0.00140	1865	23	1907	22	2.2
7029-289.1	148	76	0.53	56	4	9.66E-05	4.33E-05	0.00167	0.16749	0.01107	5.470	0.103	0.33970	0.00486	0.8276	0.11678	0.00125	1885	23	1907	19	1.2
7029-242.1	1298	27	0.02	427	4	1.00E-05	1.00E-05	0.00017	0.00601	0.00045	5.493	0.067	0.34114	0.00370	0.9350	0.11678	0.00051	1892	18	1908	8	0.8
7029-238.1	142	59	0.43	52	1	2.49E-05	3.63E-05	0.00043	0.12715	0.00389	5.562	0.110	0.34245	0.00481	0.7882	0.11779	0.00144	1898	23	1923	22	1.3
7029-224.1	119	70	0.61	43	0	1.00E-05	1.00E-05	0.00017	0.18733	0.00520	5.296	0.115	0.32452	0.00460	0.7359	0.11836	0.00176	1812	22	1932	27	6.2
7029-231.1	153	56	0.38	69	7	1.30E-04	4.25E-05	0.00225	0.10874	0.00303	8.196	0.163	0.41531	0.00546	0.7444	0.14313	0.00192	2239	25	2265	23	1.2
7029-217.1	116	281	2.50	78	0	1.00E-05	1.00E-05	0.00017	0.70641	0.00779	8.383	0.135	0.41830	0.00535	0.8595	0.14535	0.00120	2253	24	2292	14	1.7
7029-120.1	367	195	0.55	172	1	5.08E-06	7.77E-06	0.00009	0.15683	0.00348	8.437	0.114	0.41885	0.00486	0.9083	0.14610	0.00084	2255	22	2301	10	2
7029-110.1	180	127	0.73	88	2	3.42E-05	2.04E-05	0.00059	0.20946	0.00435	8.505	0.140	0.42005	0.00548	0.8577	0.14684	0.00125	2261	25	2309	15	2.1
7029-225.1	286	162	0.59	142	0	1.08E-06	1.07E-05	0.00002	0.16411	0.00321	8.925	0.166	0.44052	0.00731	0.9345	0.14693	0.00098	2353	33	2311	12	-1.8
7029-283.1	966	152	0.16	415	3	1.00E-05	1.00E-05	0.00017	0.05050	0.00087	8.473	0.105	0.41710	0.00466	0.9433	0.14734	0.00061	2247	21	2315	7	2.9
7029-222.1	116	74	0.66	57	0	3.51E-06	2.31E-05	0.00006	0.18577	0.00465	8.652	0.143	0.42538	0.00538	0.8346	0.14752	0.00135	2285	24	2317	16	1.4
7029-104.1	571	71	0.13	256	2	1.00E-05	1.00E-05	0.00017	0.03711	0.00189	9.006	0.116	0.43896	0.00487	0.9133	0.14880	0.00079	2346	22	2332	9	-0.6
7029-161.1	1076	114	0.11	476	4	1.00E-05	1.00E-05	0.00017	0.03400	0.00072	8.957	0.158	0.43487	0.00507	0.7438	0.14938	0.00178	2328	23	2339	21	0.5
7029-147.1	115	43	0.39	54	0	1.00E-05	1.00E-05	0.00017	0.10839	0.00320	9.029	0.154	0.43827	0.00653	0.9220	0.14942	0.00100	2343	29	2339	11	-0.2
7029-140.1	341	109	0.33	156	1	1.00E-05	1.00E-05	0.00017	0.09847	0.00242	8.837	0.155	0.42590	0.00519	0.7737	0.15048	0.00169	2287	23	2351	19	2.7
7029-246.1	362	192	0.55	179	2	1.80E-05	1.40E-05	0.00031	0.15541	0.00200	9.361	0.133	0.43983	0.00533	0.9082	0.15436	0.00092	2350	24	2395	10	1.9
7029-118.1	166	118	0.74	87	0	6.00E-08	3.17E-05	0.00000	0.21106	0.00388	9.546	0.177	0.44774	0.00630	0.8294	0.15464	0.00161	2385	28	2398	18	0.5
7029-128.1	80	52	0.66	44	0	8.79E-06	3.02E-05	0.00015	0.19269	0.00888	10.103	0.227	0.46862	0.00904	0.9105	0.15637	0.00146	2478	40	2417	16	-2.5
7029-243.1	374	169	0.47	189	1	4.24E-06	1.15E-05	0.00007	0.13293	0.00189	9.853	0.133	0.45526	0.00528	0.9116	0.15696	0.00088	2419	23	2423	10	0.2
7029-126.1	75	49	0.67	42	2	5.91E-05	5.39E-05	0.00102	0.18695	0.00639	10.779	0.261	0.47758	0.00895	0.8413	0.16370	0.00216	2517	39	2494	22	-0.9
7029-112.1	79	37	0.48	41	0	1.00E-05	1.00E-05	0.00017	0.14464	0.00410	10.373	0.227	0.45868	0.00802	0.8615	0.16401	0.00184	2434	36	2497	19	2.6
7029-228.1	711	45	0.07	342	34	1.17E-04	1.93E-05	0.00202	0.01860	0.00088	10.955	0.141	0.47136	0.00539	0.9342	0.16856	0.00078	2490	24	2543	8	2.1

Notes (see Stern, 1997):
Uncertainties reported at 1σ (absolute) and are calculated by numerical propagation of all known sources of error
$f206^{204}$ refers to mole fraction of total ^{206}Pb that is due to common Pb, calculated using the ^{204}Pb method; common Pb composition used is the surface blank
Discordance relative to origin = 100 * (1-($^{206}Pb/^{238}U$ age)/($^{207}Pb/^{206}Pb$ age))
* = radiogenic Pb

CXA-01-D40 (z7036)

A gabbroic to monzodioritic intrusion from the Pukatawakan Bay area, interpreted in the field to be related to a ca. 1855 Ma Chipewyan suite, was sampled for U-Pb geochronology (Fig. 2b, UTM 518996, 6319235). The intrusion locally contains up to 1% disseminated chalcopyrite and pyrite. Zircon recovery was adequate and grains were selected from the diamagnetic separate. Zircons were subdivided by morphology into four groups, the first composed of anhedral to subequant fragments, the second, of elongate and splintery fragments, the third, of well terminated prisms, and the fourth, of platy fragments. All were clear and colourless with few inclusions or fractures. Four fractions yielded concordant or slightly discordant ages with an upper intercept of 1829 +5/-2 Ma (Fig. 3c), an age identical to that of the nearby K-feldspar megacrystic granite.

CXA-01-N2 (z7032)

This sample from the Missi Falls gneiss association (Corrigan et al., 2002) is a homogeneous, one-mica tonalite to monzogranite, with minor garnet. Collected along the Churchill River (Fig. 2b, UTM 558099, 6359186), it was inferred from field relationships to be a homogeneous equivalent of the oldest plutons in the area, which are characterized by strong foliation and migmatic fabrics. Few zircons were recovered from the diamagnetic and least magnetic fractions. Zircons were selected from the magnetic at 1° side slope, maximum Amp fraction as well as from the magnetic at 3° side slope, maximum Amp fraction. The grains selected for analysis were generally elongate prisms, well faceted, and with sharp terminations, and contained few inclusions or fractures. Some cores were observed; however, care was taken to ensure that these were not submitted for TIMS analysis. Monazite was recovered from the magnetic at 0.5 Amp/10° side slope

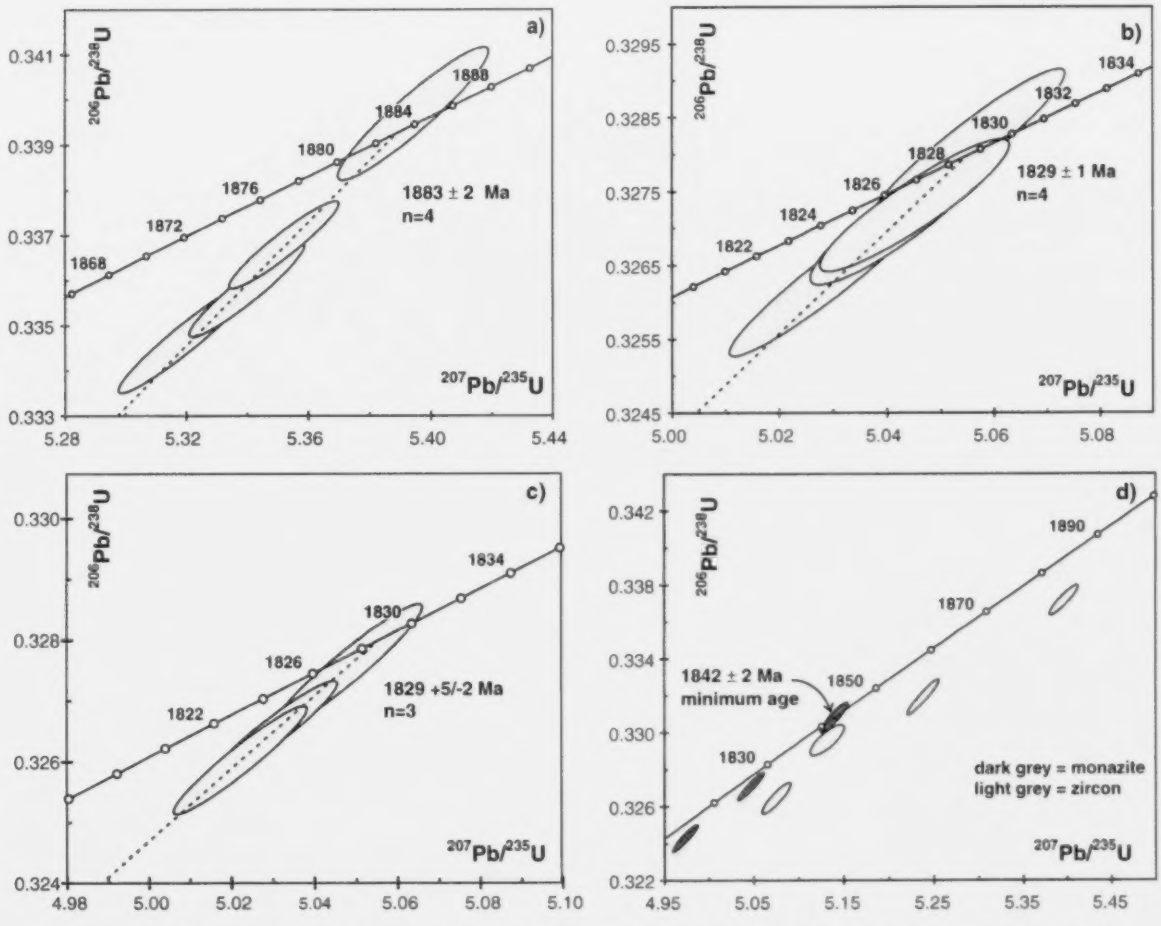

Figure 3. *Uranium-lead concordia diagrams of TIMS data. All ellipses are plotted at 2σ uncertainty.* ***a)*** *Ruttan rhyolite CXA-01-N21.* ***b)*** *Puckatawakan Bay megacrystic monzogranite CXA-01-D51.* ***c)*** *Puckatawakan Bay monzodiorite CXA-01-D40.* ***d)*** *Churchill River monzogranite CXA-01-N2.*

fraction, and three single grain fractions were submitted. Four zircon fractions plotted below concordia, with the least discordant fraction giving a $^{207}Pb/^{206}Pb$ age of 1846 ± 3 Ma (Fig. 3d). Discordant fractions A2 (multigrain fraction) and B4 (single-grain fraction) have older $^{207}Pb/^{206}Pb$ ages and are interpreted to contain inherited cores (*see* Table 1). Concordant or nearly concordant monazite ages range from 1817 Ma to 1842 Ma. The oldest monazite age can be considered a minimum crystallization age. Although the age is poorly constrained, this unit is likely related to Chipewyan Batholith emplacement with an inherited component and is likely not, as interpreted in the field, a homogeneous equivalent of older, pre-Chipewyan intrusions.

SHRIMP

CXA-01-N1 (z7031)

A layered igneous intrusion composed of ultramafic to tonalitic magmas is exposed on the north shore of Turtle Island in Southern Indian Lake. A sample of foliated quartz diorite from this intrusion was collected for U-Pb geochronology (Fig. 2b, UTM 547812, 6351095). Most zircons recovered from the diamagnetic separate were prismatic, pale brown, and contained few inclusions but numerous fractures. Many grains appear to have overgrowths, but because of their fractured appearance, these overgrowths can be difficult to observe. A second, less common, morphology consisted of pale brown fragmental zircons, with few facets, minor clear inclusions, and few fractures. Four fractions were analyzed by TIMS and the results indicate the presence of an inherited component (*see* Fig. 4). The scatter of the TIMS data made it difficult to determine precisely the igneous age or the age of the inherited material. A SHRIMP study was undertaken to resolve these questions. Detailed scanning electron microscope (SEM) images of the zircons indicated that many grains were composed of a single generation of zircon, usually with well developed oscillatory or sector zoning (Fig. 4, inset). A significant minority of grains also contained a thin, unzoned, high-U rim, with the zoned material as a core (Fig. 4a). Spot analyses of zoned regions (either cores or single-generation zircon) fall in three clusters: near 2500 Ma, between 2300 and 2400 Ma, and near 1900 Ma. Although they are not easily distinguishable on the basis of their morphology and zonation, we interpret the 2.3 to 2.4 Ga and 2.5 Ga zircons to be inherited, whereas the ca. 1.9 Ga zircons represent the igneous component. Figure 4(b, c, d) shows the similarity in appearance of both the 2.4 and 1.9 Ga zircons. Three analyses from zoned zircons gave intermediate $^{207}Pb/^{206}Pb$ ages of 1981 Ma, 2091 Ma, and 2094 Ma. These ages cannot be interpreted as resulting from mixing, as the SHRIMP spot was carefully placed on only one phase of zircon. Rather, this result may represent 2.3 or 2.5 Ga inherited zircon that was disturbed during the igneous event at ca. 1.9 Ga. Alternatively, it could represent other inherited components of distinct age. Analyses of the thin rims gave $^{207}Pb/^{206}Pb$ ages ranging from 1926 Ma to 1774 Ma, overlapping the range of ages obtained for the youngest zoned zircons (1914–1840 Ma). Two analyses (Table 2; spots 34.1 and 35.2) that provided much older ages represent mixing of the inherited and igneous components. The best estimate of the igneous age of the Turtle Island quartz diorite is 1889 ± 11 Ma (mean standard weighted deviation = 1.3, probability of fit = 23%), calculated from the weighted mean $^{207}Pb/^{206}Pb$ ages from 14 analyses of young zoned zircons and rims. Excluded from this calculation were two discordant analyses (1774 Ma and 1926 Ma). Corrigan et al. (1999b) identified an 1894 to 1886 Ma calc-alkaline plutonic suite named the 'Crowe Island Complex' in the Reindeer Lake area of Saskatchewan and interpreted it to be the plutonic root of the La Ronge island arc. These new data indicate that the Crowe Island Complex extends into Manitoba. Of economic interest, the Rottenstone Ni-PGE deposit is along strike with the Turtle Island diorite and could potentially be part of this suite; however, its age is unknown.

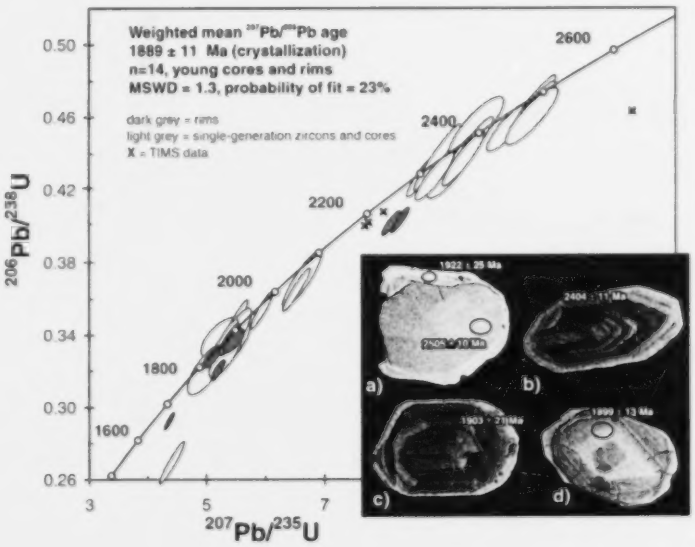

Figure 4.

Uranium-lead concordia diagram of combined TIMS and SHRIMP results from the Turtle Island quartz diorite. Ellipses are plotted at 2σ uncertainty. The inset contains images of representative zircons. Note the thin rim on grain 4a). Black ellipses on the backscattered-electron images represent approximate positions of the SHRIMP analyses. The ages provided by individual SHRIMP analyses are also shown (1σ uncertainty). MSWD = mean square of weighted deviates

fraction, and three single grain fractions were submitted. Four zircon fractions plotted below concordia, with the least discordant fraction giving a $^{207}Pb/^{206}Pb$ age of 1846 ± 3 Ma (Fig. 3d). Discordant fractions A2 (multigrain fraction) and B4 (single-grain fraction) have older $^{207}Pb/^{206}Pb$ ages and are interpreted to contain inherited cores (*see* Table 1). Concordant or nearly concordant monazite ages range from 1817 Ma to 1842 Ma. The oldest monazite age can be considered a minimum crystallization age. Although the age is poorly constrained, this unit is likely related to Chipewyan Batholith emplacement with an inherited component and is likely not, as interpreted in the field, a homogeneous equivalent of older, pre-Chipewyan intrusions.

SHRIMP

CXA-01-N1 (z7031)

A layered igneous intrusion composed of ultramafic to tonalitic magmas is exposed on the north shore of Turtle Island in Southern Indian Lake. A sample of foliated quartz diorite from this intrusion was collected for U-Pb geochronology (Fig. 2b, UTM 547812, 6351095). Most zircons recovered from the diamagnetic separate were prismatic, pale brown, and contained few inclusions but numerous fractures. Many grains appear to have overgrowths, but because of their fractured appearance, these overgrowths can be difficult to observe. A second, less common, morphology consisted of pale brown fragmental zircons, with few facets, minor clear inclusions, and few fractures. Four fractions were analyzed by TIMS and the results indicate the presence of an inherited component (*see* Fig. 4). The scatter of the TIMS data made it difficult to determine precisely the igneous age or the age of the inherited material. A SHRIMP study was undertaken to resolve these questions. Detailed scanning electron microscope (SEM) images of the zircons indicated that many grains were composed of a single generation of zircon, usually with well developed oscillatory or sector zoning (Fig. 4, inset). A significant minority of grains also contained a thin, unzoned, high-U rim, with the zoned material as a core (Fig. 4a). Spot analyses of zoned regions (either cores or single-generation zircon) fall in three clusters: near 2500 Ma, between 2300 and 2400 Ma, and near 1900 Ma. Although they are not easily distinguishable on the basis of their morphology and zonation, we interpret the 2.3 to 2.4 Ga and 2.5 Ga zircons to be inherited, whereas the ca. 1.9 Ga zircons represent the igneous component. Figure 4(b, c, d) shows the similarity in appearance of both the 2.4 and 1.9 Ga zircons. Three analyses from zoned zircons gave intermediate $^{207}Pb/^{206}Pb$ ages of 1981 Ma, 2091 Ma, and 2094 Ma. These ages cannot be interpreted as resulting from mixing, as the SHRIMP spot was carefully placed on only one phase of zircon. Rather, this result may represent 2.3 or 2.5 Ga inherited zircon that was disturbed during the igneous event at ca. 1.9 Ga. Alternatively, it could represent other inherited components of distinct age. Analyses of the thin rims gave $^{207}Pb/^{206}Pb$ ages ranging from 1926 Ma to 1774 Ma, overlapping the range of ages obtained for the youngest zoned zircons (1914–1840 Ma). Two analyses (Table 2: spots 34.1 and 35.2) that provided much older ages represent mixing of the inherited and igneous components. The best estimate of the igneous age of the Turtle Island quartz diorite is 1889 ± 11 Ma (mean standard weighted deviation = 1.3, probability of fit = 23%), calculated from the weighted mean $^{207}Pb/^{206}Pb$ ages from 14 analyses of young zoned zircons and rims. Excluded from this calculation were two discordant analyses (1774 Ma and 1926 Ma). Corrigan et al. (1999b) identified an 1894 to 1886 Ma calc-alkaline plutonic suite named the 'Crowe Island Complex' in the Reindeer Lake area of Saskatchewan and interpreted it to be the plutonic root of the La Ronge island arc. These new data indicate that the Crowe Island Complex extends into Manitoba. Of economic interest, the Rottenstone Ni-PGE deposit is along strike with the Turtle Island diorite and could potentially be part of this suite; however, its age is unknown.

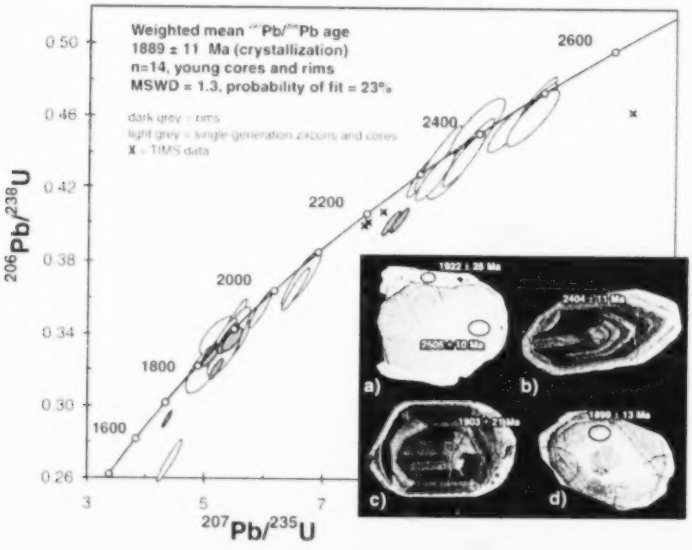

Figure 4.

Uranium-lead concordia diagram of combined TIMS and SHRIMP results from the Turtle Island quartz diorite. Ellipses are plotted at 2 σ uncertainty. The inset contains images of representative zircons. Note the thin rim on grain 4a). Black ellipses on the backscattered-electron images represent approximate positions of the SHRIMP analyses. The ages provided by individual SHRIMP analyses are also shown (1 σ uncertainty). MSWD = mean square of weighted deviates

Inherited early Paleoproterozoic ages obtained here are similar to ages of the Sask Craton, and their prevalence in this sample may suggest the presence nearby of basement.

CXA-01-N22A (z7030)

This sample is a wacke of the Powder Magazine formation, collected at the Ruttan mine site (Fig. 2a, UTM 461844, 6259503). This formation represents turbidite units in the Rusty Lake Belt that overlie the mineralized volcanic sequence. The metamorphic grade of this sample is low; original sedimentary structures including crossbedding, graded bedding, and load structures are preserved. Zircons recovered from the nonmagnetic at 10° side slope separate are generally prismatic, clear, and colourless, with numerous fractures. Facets and terminations are generally very sharp, although some grains are moderately well rounded. Scanning electron microscope images indicate that most grains contain diffuse, oscillatory zoning. Thirty-six detrital zircons, with varying degrees of roundness and zoning, were analyzed and gave ages ranging from 1822 to 1925 Ma. Plotted on a cumulative probability curve, the data form a roughly Gaussian peak, centred at approximately 1880 Ma, with a small bulge toward slightly older ages (Fig. 5a). Most ages are within error of the typical age range of arc volcanism in the Trans-Hudson Orogen (i.e 1.87–1.9 Ga). Younger ages were obtained in a small number of cases (*see* Table 2, analyses 7030-11.1, 7030-159.1) and may be the result of minor amounts of lead loss. No older material was identified, although inherited zircons have been identified in material from the volcanic mine sequence (Ames et al., 2002). Thirty-one analyses gave ages ranging from 1822 to 1907 Ma and were pooled to yield a weighted mean $^{207}Pb/^{206}Pb$ age of 1880 ± 4 Ma, with a mean standard weighted deviation of 1.07 and a probability of fit of 37%. An MSWD near unity and the high percentage of probability of fit indicate that no detectable geological scatter

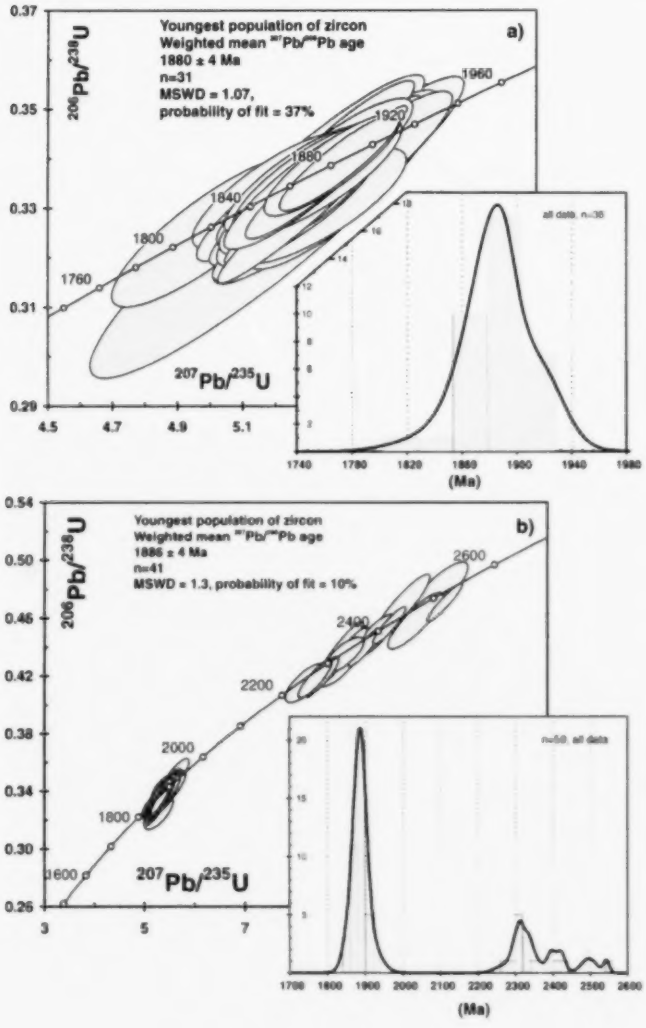

Figure 5.

*Uranium-lead concordia and cumulative probability curves of detrital zircon data collected using SHRIMP. Ellipses are plotted at 2☞ uncertainty. **a)** Powder Magazine formation CXA-02-N22A. All data are between 95% and 103% concordant and are plotted on the cumulative probability diagram. Bin width is 25 Ma. **b)** Partridge Breast conglomerate CXA-02-N3. All data are between 97% and 102% concordant and are plotted on the cumulative probability diagram. Bin width is 20 Ma. MSWD = mean standard weighted deviation*

occurs in the data set. Since the youngest zircon was not statistically distinct from the rest of the analyzed zircons, no single youngest detrital grain was identified. Instead, the data set indicates a maximum age of deposition of 1880 ± 4 Ma.

CXA-01-N3 (z7029)

A sample of polymictic conglomerate from the Partridge Breast Lake area (Fig. 2a, UTM 560331, 6359272) was collected to constrain the age of deposition as well as indirectly date locally interbedded mafic volcanic rocks. Clasts in the conglomerate were subrounded to well rounded and strongly flattened oblique to bedding; they are interpreted as predominantly igneous in origin. The conglomerate grades stratigraphically upward into psammite then into semipelite–pelite, a transition interpreted to be a facies change. The sample was sorted using a Frantz isodynamic separator only to 5° side slope/max Amps in order not to bias the sample of detrital zircons picked for SHRIMP analysis. Zircons recovered from the magnetic and nonmagnetic at 5° side slope separates were commonly prismatic with fine oscillatory zoning and sharp terminations. Numerous grains had ragged, altered, high-U rims, too small for SHRIMP analysis. Other zircons were moderately rounded with diffuse concentric zoning. Fifty-eight zircons were analyzed by SHRIMP, one grain with a duplicate spot. Ages ranged from 1853 to 2543 Ma, with the majority of the analyses (n = 41) providing ages ranging from 1853 to 1932 Ma (Fig. 5b). This subset forms a single Gaussian peak with a weighted mean $^{207}Pb/^{206}Pb$ age of 1886 ± 4 Ma (MSWD = 1.3, probability of fit = 10%) interpreted as the maximum age of deposition. This age is consistent with the ages obtained from the Lynn Lake and Rusty Lake belts. The older component, with an age range of 2265 to 2543 Ma, is comparable to the inherited ages obtained for the Turtle Island diorite (CXA-01-N1). A similar assemblage from Saskatchewan that was identified and dated by Corrigan et al. (1999a) was tentatively interpreted as a foredeep or molasse basin.

DISCUSSION AND CONCLUSIONS

This report presents a thorough description of the U-Pb results generated thus far from work carried out along the Churchill River-Southern Indian Lake transect. These new U-Pb results allow us to compare and contrast the Rusty Lake Belt, the Lynn Lake Belt, and smaller isolated supracrustal belts in the Southern Indian Domain, as well as develop ideas about the area's tectonostratigraphic evolution. Prior to the TGI study, a single age from each of the Rusty Lake (1878 Ma) and Lynn Lake (1910 Ma) belts had been used to suggest that the two belts were separate entities (Baldwin et al., 1987). New U-Pb ages from the Rusty Lake (1883 Ma, this study) and Lynn Lake (Bohm and Heaman, 2002) belts now suggest that the belts are coeval. The Powder Magazine formation, which overlies the Ruttan rhyolite in the Rusty Lake Belt, contains zircons of exclusively volcanic provenance and yields a maximum age of deposition of 1880 Ma. This sample does not give any indication of the presence of a nearby craton, although inherited zircons have been observed in other volcanic units (Ames et al., 2002). Detrital zircons from a conglomerate in the more northerly Partridge Breast Belt were also analyzed using SHRIMP. The sample was dominated by ca. 1885 Ma zircons, the same age as that obtained from the Rusty Lake Belt. However, the sample also contained a number of early Paleoproterozoic to late Archean zircons, suggesting a molasse or foredeep setting in proximity to the Sask Craton (Corrigan and Rayner, 2002).

A 1829 Ma megacrystic monzogranite, enclosing rafts of folded sedimentary rocks at Pukatawakan Bay, has been identified. Previous workers suggested that the sedimentary rocks were related to the Sickle Group (Cranstone, 1972), whereas others referred to them as the 'arkosic suite' until their origin could be determined (Lenton and Corkery, 1981). The Park Island assemblage in Saskatchewan, a sedimentary sequence cut by the 1.85 to 1.86 Wathaman Batholith and interpreted as a foredeep or molasse basin (Corrigan et al., 1999b), is similar in appearance to the sedimentary rocks enclosed by the megacrystic monzogranite. Had the sedimentary rocks at this locality been intruded by an older (ca. 1.85–1.86 Ga) Wathaman granite, it would have been possible to link them to the Park Island assemblage. However, the younger 1.83 Ga age for the megacrystic granite does not help resolve the affinity of these sedimentary rocks to either the Sickle Group or the Park Island assemblage. These ca. 1.83 Ga intrusions may represent a previously unrecognized later pulse of the Wathaman Batholith, or part of the 1.83 Ga Nueltin Suite (Peterson et al., 2002).

A homogeneous monzogranite from the Churchill River was sampled in the hope that it would represent basement to the supracrustal rocks. Uranium-lead TIMS results yielded a minimum crystallization age of 1842 Ma with some indication of inherited zircon. Older material was more clearly identified in the northern end of Southern Indian Lake. The 1889 Ma Turtle Island quartz diorite is interpreted as being associated with the Crowe Island Complex in Saskatchewan, and thus may represent the plutonic root of the La Ronge–Lynn Lake arc. However, it contains a significant number of 2.4 to 2.5 Ga inherited zircons. This is the first indication of the potential presence of Sask Craton-age crust in this area, which may be of interest to diamond explorationists.

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